REMARKS

The Office Action of September 17, 2004 has been received and reviewed. Claims 1-44 are currently pending in the application. Claims 11-26 and 31-44 are withdrawn from consideration as being directed to a non-elected invention. Claims 1-10 and 27-30 stand rejected. Claims 1-3, 5-10 and 27-30 have been amended as set forth herein. All amendments are made without prejudice or disclaimer. Reconsideration is requested.

Priority

The Office Action indicated that a certified copy of the priority document EPO/00204697.7 was not received. (Office Action of September 17, 2004, hereinafter referred to as the "Office Action," at page 2). Applicants have requested a certified copy of the priority document which will be forwarded to the Office upon receipt.

Election/Restriction

Applicants previously elected Group I in a telephone conversation with the examiner. Applicants affirm election of the claims of Group I, including claims 1-10 and 27-30, without traverse.

Information Disclosure Statement

The Office Action requested that copies of IDS references be provided. (Office Action, at page 4). As evidenced by the postcard receipt (copy enclosed), copies of these references were already provided to the Office and received by the Office. Accordingly, applicants do not believe that they should be charged for late submission of the documents. Be that as it may, enclosed herewith are copies of the crossed-through references indicated in the Information Disclosure Statement accompanying the Office Action.

Objections to the Specification

Sequence Listing and Identifiers

The Office Action indicated that Figure 1 does not comply with 37 C.F.R. §§ 1.821-1.825 because the sequence referred to in Figure 1 lacked a sequence identifier. (Office Action, at page 4). The Office Action also indicated that sequences on pages 19 and 21 lacked sequence identifiers. (Id.). Pursuant to 37 C.F.R. §§ 1.121 and 1.125 (as amended to date), a substitute Specification is submitted incorporating sequence identifiers where appropriate. Other amendments were made to the Specification and Abstract in an effort to conform more closely to U.S. practice. No new matter has been added.

In view of the amendments, applicants respectfully request that the objection be withdrawn.

Use of Trademarks in the Specification

The Office Action notes the use of the trademarks Prism™ and CODOP. (Office Action at page 5). Section 608.01(v) of the M.P.E.P. states that "if the product to which the trademark refers is set forth in such language that its identity is clear, the examiners are authorized to permit the use of the trademark if it is distinguished from common descriptive nouns by capitalization." (M.P.E.P. § 608.01(v)). The Specification has been amended to capitalize the trademark PRISM™. PRISM™ is a non-descriptive trademark and is clearly identified as an automated sequencer. (Specification, as-filed, at page 19, line 18). CODOP, found at page 20, line 25 in the as-filed Specification, is clearly identified as a software program, is not a common descriptive noun and is capitalized.

Reconsideration and withdrawal of the objections to the Specification are requested.

Objections to the Claims

Claims 1 and 8 were objected to as assertedly reciting acronyms without providing corresponding definitions. (Office Action, at page 5). Claim 1 has been amended to recite in part a method for producing mRNA encoding a *Plasmodium* apical membrane antigen-1 (AMA-

1) ectodomain, or a functional part thereof, functional derivative thereof, functional analogue thereof, or any combination thereof, in a yeast cell. The grammatical error has also been corrected in claims 1 and 27, as suggested by the Office Action. Claim 8 has been amended to recite the method according to claim 7, wherein the mRNA encoding *Plasmodium* AMA-1 ectodomain comprises mRNA encoding *Plasmodium falciparum* Vietnam-Oak Knoll strain ectodomain.

Claim 27 was objected to for including elements from a withdrawn claim. (Office Action at page 5). Claim 27 has been amended to recite the elements of withdrawn claim 11 and, as amended, recites a process for producing a *Plasmodium* apical membrane antigen-1 (AMA-1) ectodomain or a functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, said method comprising: providing a yeast cell with an isolated or recombinant nucleic acid encoding *Plasmodium* AMA-1 ectodomain or a functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, said nucleic acid being modified to utilize a yeast cell's codon usage; and, collecting formed *Plasmodium* AMA-1 ectodomain or functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof.

Reconsideration and withdrawal of the objections to claims 1, 8 and 27 are requested.

Rejections Under 35 U.S.C. § 112, Second Paragraph

Claims 1-10 and 27-30 stand rejected under 35 U.S.C. § 112, second paragraph, for assertedly "failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention." (Office Action, at page 6). Partly in view of the amendments to claims 1-3, 5, 6, 27 and 28, reconsideration and withdrawal of the indefiniteness rejections are requested.

Specifically, it was asserted that the phrase and/or "confers ambiguity as to what the nucleic acid molecule is encoding." (Office Action, at page 6). Though applicants do not agree with this assertion, claims 1, 3, 27 and 28 have been amended to recite, in part, a functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof.

Claim 5 has been amended to remove the phrase "and/or" and, as amended, recites the method according to claim 1, wherein at least one site in said mRNA encoding a *Plasmodium* AMA-1 ectodomain comprising a glycosylation signal, has been removed.

The Office Action further asserts that the phrase "allowing for expression" is unclear. (Office Action, at page 6). Though applicants do not agree with the assertion, claim 2 has been amended to remove the phrase "allowing for expression" and, as amended, recites the method according to claim 1, further comprising expressing said nucleic acid in said yeast cell.

The Office Action also asserts that the term "purifying" in claims 3 and 28 "is a subjective and relative term, thus conferring ambiguity and indefiniteness to the claim." (Office Action, at page 6). As stated in M.P.E.P. § 2106.C, "[c]laims and disclosures are not to be evaluated in a vacuum. If elements of an invention are well known in the art, the applicant does not have to provide a disclosure that describes those elements." The term "purifying" is used throughout the as-filed Specification, for instance at page 4, lines 21-23 ("purified from said yeast cell and/or culture medium"), page 7, lines 21-24 ("[h]eterogeneous products may be difficult to reproducibly purify to acceptable standards under GMP, and such heterogeneity may create batch to batch variation in an immunogenic property of the product (given the published effects of N-linked glycosylation on immunogenicity)."), page 27, lines 9-11 ("[f]or purification, best results were obtained by direct binding of Pf AMA-1 on an immobilized metal affinity column activated with $CuSO_4$ (IMAC)."), and beginning on page 27, at line 25, and ending at page 29, line 20, several pages are devoted to the disclosure of purification strategies. Thus, one of ordinary skill in the art would have understood what was meant by "purifying" as recited in claims 3 and 8. Furthermore, requiring applicants to specify exactly which process is used to purify *Plasmodium* AMA-1 ectodomain is unreasonable since there are a myriad protein purification protocols known to one of ordinary skill in the art.

Claim 6 has been amended to remove the number "20." (Office Action, at page 7).

Claims 4, 6-10, 29 and 30 are definite, *inter alia*, as depending from a definite base claim, claims 1 and 27.

Reconsideration and withdrawal of the indefiniteness rejection of claims 1-10 and 27-30

are requested.

Rejections Under 35 U.S.C. § 112, First Paragraph

Claims 1-10 and 27-30 stand rejected under 35 U.S.C. § 112, first paragraph, for assertedly "failing to comply with the written description requirement." (Office Action, at page 7). Applicants respectfully traverse the rejections.

The Office Action asserts that claims 1-10 and 27-30 "contain subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention." (Office Action, at page 7). Specifically, it was asserted that "the claims are directed to a genus of nucleic acid molecules that encode an AMA-1 ectodomain or a part, derivative or analog thereof, with a single disclosed functionality – the requirement that each molecule encodes an antigen that will produce protective immunity" and that the genus of "any nucleic acid molecule encoding any portion of any *Plasmodium* AMA-1 ectodomain having protective immunogenic functionality" was not supported by a sufficient number of examples of particular embodiments for such nucleic acid molecules in the Specification. (Office Action, at page 7).

Applicants have elected Group I, claims 1-10 and 27-30, which is described by the Office Action as "a method of producing mRNA encoding a *Plasmodium* Apical Membrane Antigen-1 (AMA-1) ectodomain." (Office Action, at page 2). Claim 1, as amended, recites a method for producing mRNA encoding a *Plasmodium* apical membrane antigen-1 (AMA-1) ectodomain, or functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, in a yeast cell, the method comprising: providing the yeast cell with a nucleic acid encoding said ectodomain or functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, the nucleic acid being modified to utilize the yeast cell's codon usage. Amended claim 27 recites a process for producing a *Plasmodium* apical membrane antigen-1 (AMA-1) ectodomain or a functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, the method comprising:

providing a yeast cell with an isolated or recombinant nucleic acid encoding *Plasmodium* AMA-1 ectodomain or a functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof, the nucleic acid being modified to utilize a yeast cell's codon usage; and, collecting formed *Plasmodium* AMA-1 ectodomain or functional part thereof, functional derivative thereof, functional analog thereof, or any combination thereof.

By "functional part" is meant "a part of said nucleic acid, at least 30 base pairs long, preferably at least 200 base pairs long, comprising at least one expression characteristic (in kind not necessarily in amount) as a nucleic acid of the invention. Preferably but not necessarily said part comprises an immunogenic property of an AMA-1 ectodomain." (Specification, as-filed, at page 10, lines 25-30). The as-filed Specification, at pages 5, disclose that "[b]y immunogenic property is meant the capability to induce an immune response in a host. Preferably, said immunogenic property comprises a property to induce an immune response against a conformational epitope on a native AMA-1 ectodomain." (Specification, as-filed, at page 5, lines 11-14). The as-filed Specification provides sufficient guidance to one of ordinary skill in the art through at least five different examples which have an immunogenic property; the five different structures "react with a monoclonal antibody." (Specification, as-filed, at page 24, line 16 to page 26, line 15 and Office Action, at page 8). Ability of a peptide to bind to an antibody is an immunogenic property. Thus, these five different examples have an immunogenic property and are functional parts of the AMA-1 ectodomain, as defined in the Specification and as recited in independent claims 1 and 27.

Since several examples are disclosed by the as-filed Specification demonstrating the subject matter claimed within the elected Group I, a person of ordinary skill in the art would recognize that applicants were in possession of the invention.

Claims 2-10 and 28-30 are sufficiently described, *inter alia*, as depending from a sufficiently described base claim, claims 1 and 27.

Reconsideration and withdrawal of the written description rejections are requested.

Rejections Under 35 U.S.C. § 102(a)

Claims 1-3, 5, 6, 9, 10 and 27-30 stand rejected under 35 U.S.C. § 102(a) as assertedly being anticipated by Kocken *et al.*, "High-Level Expression of the Malaria Blood-Stage Vaccine Candidate *Plasmodium falciparum* Apical Membrane Antigen 1 and Induction of Antibodies That Inhibit Erythrocyte Invasion," Infection and Immunity, 70(8):4471-4476 (2002). (Office Action, at page 10). Applicants traverse the anticipation rejection as hereinafter set forth.

The Office Action asserts that "the limitation 'modification' is interpreted as broadly as reasonable to read on any change/alteration of the site." (Office Action, at page 10). Claims 1 and 27, as amended, recite, in part, providing the yeast cell with a nucleic acid . . . the nucleic acid being *modified to utilize the yeast cell's codon usage* (emphasis added).

Kocken *et al.*, does not disclose modification of the nucleic acid sequence such that it is optimized to match the specific frequency of codon usage of an organism of choice. Kocken, *et al.* does not disclose a nucleic acid "being modified to utilize said yeast cell's codon usage" as recited by amended claims 1 and 27. Kocken *et al.* discloses mutation of various codons only for the purpose of avoiding glycosylation and hyper-glycosylation. (Kocken *et al.*, at 45).

Furthermore, page 13, lines 4-9 of the as-filed Specification discloses modification of the nucleic acid of the invention to utilize codon usage of other eukaryotic systems, or bacteria, as desired. One of ordinary skill in the art knows the frequency of use of various codons coding for the same amino acid varies between organisms. Thus, one of ordinary skill in the art would understand that the as-filed Specification discloses optimization of the nucleic acid codons for expression such that the codons in the nucleic acid are those most frequently used in the host. For example, the as-filed Specification, at page 20, lines 23-25, discloses the use of a computer software program, called CODOP, to design the sequence of the synthetic nucleic acid based on the frequency of codon usage for *P. pastoris*. Further, the as-filed Specification, at page 20, lines 23-25, states that "[t]his program allows codon optimisation with host organism preference."

Thus, Kocken *et al.* does not anticipate the present application because the reference does not disclose every element recited in amended independent claims 1 and 27.

Claims 2, 3, 5, 6, 9, 10 and 28-30 are not anticipated, *inter alia*, as depending from non-

anticipated base claims, claims 1 and 27.

Reconsideration and withdrawal of the anticipation rejections are requested.

Double Patenting Under 35 U.S.C. § 101

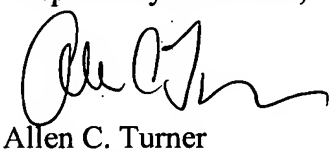
Claims 1-10 and 27-30 stand provisionally rejected under 35 U.S.C. § 101 as assertedly claiming the same invention as that of claims 1-10 and 27-30 of copending U.S. Patent Application No. 10/468,761. (Office Action, at page 11). Applicants traverse the provisional rejection as hereinafter set forth.

This application is a continuation of PCT International Patent Application No. PCT/NL/01/00934, filed on December 21, 2001, designating the United States of America, and published, in English, as PCT International Publication No. WO 02/052014 A2 on July 4, 2002. Applicants petitioned under 37 C.F.R. § 1.137(b) for revival of International Patent Application No. PCT/NL01/00934 abandoned under 35 U.S.C. § 371(d). The Office granted this petition on September 25, 2003. (PCT Legal Examiner Decision, dated September 25, 2003). The parent application, PCT/NL01/00934, was "revived for the purposes of continuity only" and when continuity was established by the decision to grant revival, the parent was again abandoned in favor of the present continuing application. (Id.). Furthermore, U.S. Application No. 10/468,761 now appears to be abandoned, thus rendering the rejection moot.

CONCLUSION

In view of the foregoing amendments and remarks, the claims should define patentable subject matter and notice of allowance is requested. Amendments to the specification and abstract were made to more closely conform to U.S. practice. No new matter was added. If any questions remain after consideration of the foregoing, the Office is invited to contact the applicants' attorney at the address or telephone number given herein.

Respectfully submitted,



Allen C. Turner
Registration No. 33,041
Attorney for Applicants
TRASKBRITT, P.C.
P.O. Box 2550
Salt Lake City, Utah 84110-2550
Telephone: 801-532-1922
Facsimile: 801-531-9168

Date: February 16, 2005

Enclosures: Appendix A (clean version of substitute specification)
Appendix B (marked-up version of substitute specification showing changes)

APPENDIX B

(VERSION OF SUBSTITUTE SPECIFICATION WITH MARKINGS TO SHOW CHANGES MADE)

(Serial No. 10/615,615)

Title of Invention:

EFFICIENT EXPRESSION OF PLASMODIUM APICAL MEMBRANE ~~ANTIGEN~~ ANTIGEN-1 IN YEAST CELLS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of PCT International Patent Application No. PCT/NL/01/00934, filed on December 21, 2001, designating the United States of America, and published, in English, as PCT International Publication No. WO 02/052014 A2 on July 4, 2002, the contents of the entirety of which is incorporated herein by this reference.

TECHNICAL FIELD

[0002] The invention relates to the fields of medicine and biotechnology, vaccines and diagnostics. More in ~~particular~~ particular, the invention relates to the intervention ~~with~~ and the diagnosis of ~~Plasmodium induced~~ *Plasmodium*-induced malaria.

BACKGROUND

[0003] Malaria is a ~~wide spread~~ widespread disease in most ~~(sub)tropical~~ subtropical countries. It is acquired by infection with a malaria parasite. The socioeconomic impact of this disease is enormous. Malaria exists in different forms, caused by different parasites. The symptoms vary considerably between the different forms.

[0004] ~~Plasmodium vivax and Plasmodium falciparum~~ *Plasmodium vivax* and *Plasmodium falciparum* are the two most important human malaria parasites. Other human malaria parasites are ~~Plasmodium ovale and Plasmodium malariae,~~ *Plasmodium ovale* and *Plasmodium malariae,* but these two species are less pathogenic than ~~P. vivax and P. falciparum. P. vivax~~ *P. vivax* and *P. falciparum*. *P. vivax* causes less mortality than ~~P. falciparum.~~ *P. falciparum.* Treatment of ~~P. falciparum~~ *P. falciparum* is becoming more complicated, because ~~chloroquine resistant P. falciparum~~ chloroquine-resistant *P. falciparum* parasites are spreading rapidly and ~~multidrug resistant~~ multidrug-resistant parasites have also developed. In addition, ~~chloroquine resistant P. vivax~~ chloroquine-resistant *P. vivax* has been detected, indicating similar problems in the treatment of ~~P. vivax as for P. falciparum.~~ *P. vivax* as for *P. falciparum.*

[0005] At present, there is essentially no effective vaccine available against malaria, at least not for use in humans. Accumulated data, including that from ~~non-human~~ nonhuman primate[1, 2] and rodent studies,[3, 4] have indicated that the apical membrane antigen-1 (AMA-1) family of molecules is a target for protective immune responses. In all ~~Plasmodium~~ *Plasmodium* species reported to date, with the exception of ~~Plasmodium falciparum[5] and P. reichenowi[6]~~ *P. falciparum*[5] and *P. reichenowi*[6] that form a phylogenetic clade distinct from other malaria parasites, AMA-1 is synthesized ~~de novo~~ *de novo* as a 66 kDa transmembrane protein. The protein contains a predicted N-terminal signal sequence, an ectodomain, a predicted transmembrane region and a C-terminal cytoplasmic domain. The ectodomain is further divided into three domains (domain I, II and III) defined by disulfide bonds.[7] In *P. falciparum* and *P. ~~reichenowi~~ reichenowi*, the protein is expressed as an 83 kDa protein having an N-terminal extension as compared to the 66 kDa forms, referred to as the prosequence. ~~Intra-species~~ Intraspecies sequence polymorphism due to point mutations[8, 9, 10] reveals clustering of mutations in particular domains of the molecule. Despite this, between species there is considerable conservation of primary amino acid structure and predicted secondary structure. Evidence to date indicates that protection invoked by AMA-1 is directed at conformational epitopes[1, 3, 4, 11] located in the AMA-1 ectodomain. ~~Immunisation~~ Immunization with reduced AMA-1 fails to induce parasite inhibitory ~~antibodies[3, 11]~~ antibodies, [3, 11] and so far only those monoclonal antibodies that recognize reduction-sensitive conformational AMA-1 epitopes have been shown to inhibit parasite multiplication *in vitro* for *P. knowlesi*[12, 13] and *P. falciparum.*[6, 14] This indicates that for an AMA-1 ~~vaccine~~ vaccine, the correct conformation will be critical.

[0006] Recombinant expression of *P. falciparum* AMA-1 (Pf AMA-1) in a ~~conformational~~ conformationally relevant way that allows production of clinical grade material has been notoriously difficult. One characteristic important for recombinant expression techniques is the unusually high A+T content of *P. falciparum* codons in comparison to most other organisms ~~and in particular~~ and, in particular, in comparison to most other organisms generally used for recombinant protein expression. The group of Prof. Anders (WEHI, Australia) has developed expression of the ectodomain in *E. coli*, followed by a refolding protocol, but scaling up this process to levels that allow production of clinical grade material has proven cumbersome. Because eukaryotic expression systems are likely to produce material with

the correct disulphide bonds directly, we have focused upon expression in such systems. Expression of the ~~full-length~~ full-length 622 amino acids long Pf AMA-1 protein (7G8 strain) in insect cells using recombinant baculovirus resulted in expression on the surface of insect cells.[15] The protein migrated in SDS-PAGE more slowly than the native ~~molecule~~ molecule, indicating glycosylation. Expression in the presence of tunicamycin confirmed this. ~~Said~~ The Pf AMA-1 protein was used to raise rat monoclonal antibodies (mAbs), some of which could block parasite multiplication in an *in vitro* assay. These functional mAbs ~~recognised~~ recognized a conformational epitope located in the ectodomain of ~~Pf AMA-1~~ Pf AMA-1. Reactivity with these mAbs, especially with mAb 4G2, is used as one assay for proper folding of recombinant Pf AMA-1. Relatively low expression levels did not allow the baculovirus ~~sytem~~ system to be developed for the production of clinical grade material.

[0007] We have obtained ~~high level~~ high-level expression of *P. vivax* AMA-1 (Pv AMA-1) ectodomain in the methylotrophic yeast *Pichia pastoris*.[16] However, this expression system is not likewise suitable to produce a secreted ectodomain of Pf AMA-1. Using the same expression vector as has successfully been used for Pv AMA-1, recombinant Pf AMA-1 *P. pastoris* clones do not express Pf AMA-1 ectodomain at any level. Analysis of total RNA extracted from induced cultures revealed only truncated mRNA products for ~~Pf AMA-1. So~~ Pf AMA-1, so no effective expression of Pf AMA-1 was possible until the present invention. This was a problem because expression of homogeneous Pf AMA-1 in high amounts is highly desirable. Efficient production of Pf AMA-1 gives possibilities to develop a ~~diagnostics,~~ diagnostics or a vaccine and/or a medicine against *P. falciparum* and/or other *Plasmodium* species. Presently, such a vaccine or medicine is not available.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention provides a method for producing mRNA encoding the *Plasmodium* AMA-1 ectodomain, or a functional part, ~~derivative~~ derivative, and/or analogue thereof, in a yeast cell, comprising providing ~~said~~ the yeast cell with a nucleic acid encoding ~~said~~ the *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, ~~said~~ the nucleic acid being modified to utilize ~~said yeast's~~ the yeast cell's codon usage. Preferably, ~~said~~ the ectodomain is derived from ~~a~~ an 83 kDa AMA-1 protein.

~~Particularly~~ Particularly, the ~~ectodomain~~ ectodomains of 83 kDa AMA-1 proteins are difficult to express in yeast cells. More ~~preferably, said~~ preferably, the 83 kDa AMA-1 protein is derived from ~~*Plasmodium*~~ *P. falciparum*. Now that a method of the invention is available, it is also possible to produce an analogous protein, such as a complete AMA-1 protein. ~~Thus~~ Thus, the invention also provides a method for producing mRNA encoding *Plasmodium* AMA-1 protein, or a functional part, ~~derivative~~ derivative, and/or analogue thereof, in a yeast cell, comprising providing ~~said~~ the yeast cell with a nucleic acid encoding ~~said~~ the *Plasmodium* AMA-1 protein, ~~said~~ the nucleic acid being modified to utilize ~~said yeast's~~ the yeast cell's codon usage. AMA-1 ectodomain produced with a method of the invention comprises at least one conformational epitope that is comparable to a conformational epitope in the native AMA-1 ectodomain, produced by the parasite, preferably in a human host. The AMA-1 ectodomain of the invention can be used for vaccination purposes and for diagnostic purposes.

[0009] With a method of the invention, it is possible to obtain mRNA encoding the AMA-1 ectodomain in a yeast cell. In ~~said~~ the yeast cell, ~~said~~ mRNA is efficiently translated into a functional AMA-1 ectodomain. With the teachings of the invention, a person skilled in the art is able to produce a functional part, ~~derivative~~ derivative, and/or analogue of ~~said~~ the ectodomain comprising at least one immunogenic property of native ectodomain in ~~kind~~ kind, not necessarily in amount.

[0010] In a preferred ~~embodiment~~ embodiment, a method of the invention further comprises allowing for expression of ~~said~~ the *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof in said~~ thereof, in the yeast cell. Preferably, ~~said~~ the AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, is purified from ~~said~~ the yeast cell and/or culture medium.

[0011] By a ~~*Plasmodium*~~ "*Plasmodium* AMA-1 ~~ectodomain~~ ectodomain" is meant herein a part of a *Plasmodium* AMA-1 protein which is normally present between the N-terminal signal sequence and the transmembrane region of a naturally occurring *Plasmodium* AMA-1 protein. In ~~*Plasmodium*~~ *P. falciparum*, ~~said~~ the ectodomain normally spans amino acid residues 25 to 545. In a preferred ~~embodiment~~ embodiment, an ectodomain of the invention spans an amino acid sequence corresponding to amino acid residues 25 to 545 in ~~*Plasmodium*~~ *P. falciparum*.

[0012] A functional part of a *Plasmodium* AMA-1 ectodomain is defined herein as a part which comprises at least one immunogenic property of ~~said~~ the AMA-1 ectodomain in kind, not necessarily in amount. Preferably, ~~said~~ the functional part comprises at least part of the prosequence, domain I, domain II and/or domain III of a ~~*Plasmodium*~~ *P. falciparum* AMA-1 ectodomain. More preferably, ~~said~~ the functional part spans an amino acid sequence corresponding to amino acid residues 25-442, 97-318, 97-442, 97-545, 303-442, 303-544, and/or 419-544 in ~~*Plasmodium*~~ *P. falciparum*.

[0013] In one ~~embodiment said~~ embodiment, the functional part comprises a subdomain of ectodomain, which can be ~~defined for instance~~ defined, for instance, by disulphide bond patterning.[7] By ~~immunogenic property~~ "immunogenic property" is meant the capability to induce an immune response in a host. Preferably, ~~said~~ immunogenic property comprises a property to induce an immune response against a conformational epitope on a native AMA-1 ectodomain. A functional derivative of a *Plasmodium* AMA-1 ectodomain is defined as a *Plasmodium* AMA-1 ectodomain which has been altered such that at least one immunogenic property of ~~said~~ the molecule is essentially the same in kind, not necessarily in amount. A derivative can be provided in many ways, for ~~instance~~ instance, through conservative amino acid substitution. A derivative can also be a fusion of the AMA-1 ectodomain or a part thereof with a second protein. In a preferred ~~embodiment said~~ embodiment, the derivative comprises one or more amino acids from variant AMA-1 ectodomains. The resultant AMA-1 ectodomain is a consensus AMA-1 ectodomain having no naturally occurring counterpart. A person skilled in the art is well able to generate analogous compounds of a *Plasmodium* AMA-1 ectodomain. This ~~can for instance~~ can, for instance, be done through screening of a peptide library. Such an analogue comprises at least one immunogenic property of a *Plasmodium* AMA-1 ectodomain in kind, not necessarily in amount. For the present ~~invention~~ invention, complete AMA-1 protein and shorter versions comprising a complete ectodomain are analogous to ectodomain.

[0014] Compared to the reported Pf AMA-1 genes, the A+T(U) content of a nucleic acid of the invention is reduced without changing amino acid sequences (with the exception of glycosylation sites, as described below). ~~Preferably said~~ Preferably, the A+T(U) content is reduced in a putative yeast polyadenylation consensus sequence to prevent premature termination of transcription. Such sequences are highly A+T rich and are thus more likely to be

present within the A+T rich coding sequences of *P. falciparum* genes. Thus, one embodiment of the invention discloses a method of the invention, wherein at least one putative yeast polyadenylation consensus sequence in ~~said~~ the nucleic acid has been modified.

[0015] Another problem for expression in eukaryotic systems is N-glycosylation. *P. falciparum* blood stage proteins are not N-glycosylated by the parasite. However, Pf AMA-1 ~~contains 6~~ contains six N-glycosylation sites that are potentially ~~recognised~~ recognized by other eukaryotic systems. ~~Full length~~ Full-length 7G8 Pf AMA-1 expressed in insect cells is glycosylated. Expression of Pv AMA-1 ectodomain in *Pichia* showed heterogeneous glycosylation of the recombinant product.[16] This could only partly be prevented by the addition of extremely high levels of tunicamycin to induction cultures, at the cost of a large drop in expression levels. Deglycosylation using N-glycosidase F was only complete after full denaturation of the protein, a process which would need refolding protocols to obtain properly folded material. Therefore, a preferred embodiment of the invention discloses a method of the invention, wherein at least one site in ~~said~~ the *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, that is generally glycosylated by eukaryotic expression ~~systems,~~ systems is removed. ~~Said~~ These sites may generally be glycosylated by eukaryotic expression systems through the N-glycosylation pathway. ~~Said~~ The site may be removed by mutating the nucleic acid sequence encoding ~~said~~ the site. This may lead to a change of at least one amino acid composing ~~said~~ the site. ~~Said~~ This change may decrease ~~said~~ the eukaryotic system's capability of glycosylating ~~said~~ the site. Alternatively, amino acids which are part of ~~said~~ the site may be removed without substitution. This may be accomplished by removing a part of the nucleic acid encoding ~~said~~ the site. In the present ~~invention~~ invention, it has been found that at least one *Plasmodium* AMA-1 ectodomain potential glycosylation site can be altered to prevent glycosylation at ~~said~~ the site in a eukaryotic host, while ~~said~~ the altered *Plasmodium* AMA-1 ectodomain retains a capability of raising a cross-reaction immune response in an animal against an unmodified *Plasmodium* AMA-1 protein.

[0016] The reasoning for removing a glycosylation site is three-fold. ~~Firstly~~ First, the presence and location of N-linked glycosylation can have profound but unpredictable targeting and focusing effects on the immune response to proteins.[17] In this context, the Pf AMA-1

baculovirus product had been used in protection studies in Aotus monkeys. These unpublished studies did not show a protective effect of AMA-1 ~~immunisation.~~ immunization. Although one explanation for this may have been that a ~~sub-optimal~~ suboptimal adjuvant was used to formulate the antigen, we reasoned that the glycosylation of the Pf AMA-1 may also have significantly influenced the immune response in ~~a non-beneficial~~ an unbeneficial way. ~~Secondly~~ Second, glycosylation is frequently heterogeneous (as demonstrated by expression of the native sequence Pv AMA-1 ectodomain in ~~Pichia).~~ *Pichia*). Heterogeneous products may be difficult to reproducibly purify to acceptable standards under GMP, and such heterogeneity may create ~~batch-to-batch~~ batch-to-batch variation in an immunogenic property of the product (given the published effects of N-linked glycosylation on immunogenicity). ~~Thirdly,~~ Third, we wished to produce a protein with the least heterogeneity in order to prepare crystals for crystallographic determination of structure. It is generally accepted that the more homogeneous the protein, the higher the chances of successful crystal formation.

[0017] Based on the molecular weight of expressed AMA-1 protein in various *Plasmodium* ~~species~~ species, two groups of *Plasmodium* species can be identified. Those expressing an AMA-1 protein of approximately 66 kDa and those expressing an AMA-1 protein of approximately 83 kDa. A method of the invention is particularly suited to increase levels of expression of ectodomain of the approximately 83 kDa AMA-1 protein in yeast. Measuring the exact molecular weight of a protein is always a difficult ~~task, thus~~ task; thus, for the present ~~invention~~ invention, the number of 83 kDa should be taken as a guidance for the actual molecular weight of ~~said~~ the AMA-1 protein. Variations of 10% in the estimates for molecular weight of a given protein are not abnormal. However, considering the large difference between the two variants of AMA-1 (66 versus 83 ~~kDa)~~ kDa), the size indication is only required to help a person skilled in the art determine whether the AMA-1 protein at hand belongs to one or the other class. A variation in the molecular weight measurements of 10% can easily be tolerated while still being able to select one of the two classes of AMA-1 proteins. ~~Thus~~ Thus, in a preferred embodiment of the ~~invention said~~ invention, the *Plasmodium* belongs to the clade whose members normally express ~~said~~ the AMA-1 protein as an approximately 83 kDa protein. "Normally" is herein defined as under conditions occurring in nature. As has already been described in this disclosure, *P. falciparum* and *P. reichenowi* belong to ~~said~~ the clade which has

the characteristic of expressing ~~said~~ the AMA-1 protein as an 83 kDa protein. Another preferred embodiment of the invention discloses a method ~~of the invention~~, wherein ~~said~~ the *Plasmodium* comprises ~~*Plasmodium*~~ *P. falciparum*. Preferably, ~~said~~ the *Plasmodium* comprises ~~*Plasmodium*~~ *P. falciparum* FVO. We have developed the Pf AMA-1 sequence from the FVO strain of *P. falciparum* for expression in *P. pastoris* for several reasons. The challenge strain that is likely to be used in phase II clinical trials is the 3D7 clone of NF54. The FVO strain has an AMA-1 sequence that is one of the most divergent from 3D7 reported to date, ~~and therefore immunisation~~ and, therefore, immunization with FVO AMA-1 would allow for a markedly heterologous challenge. Because of the possibility that polymorphism in AMA-1 is selected and maintained because of immune pressure, the availability of two extremes of diversity for clinical testing apart and in combination will be extremely informative. In addition, the FVO strain has been adapted to grow in *Aotus lemurinus griseimembra* monkeys, thus allowing preclinical evaluation with homologous challenge possibilities in this ~~non human~~ nonhuman primate system. FVO as well as 3D7 strains react with mAb 4G2, showing epitope conservation between the divergent AMA-1 sequences.

[0018] Another preferred embodiment of the invention discloses a method according to the invention, wherein ~~said~~ the yeast is *Pichia*. Yet another preferred embodiment of the invention discloses a method according to the invention, wherein ~~said~~ the yeast is *Pichia pastoris*.

[0019] In another ~~aspect~~ aspect, the present invention discloses an isolated and/or recombinant nucleic acid sequence encoding the *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, ~~said~~ the nucleic acid being modified to utilize a ~~yeast's~~ yeast cell's codon usage. A functional part, ~~derivative~~ derivative, and/or analogue of an AMA-1 ectodomain comprises at least one conformational epitope of the native AMA-1 ~~ectodomain, preferably said~~ ectodomain; preferably, the conformational epitope is an ectodomain epitope. ~~Preferably said~~ Preferably, the nucleic acid encodes a ~~*Plasmodium*~~ *P. falciparum* AMA-1 ectodomain, more ~~preferably a *Plasmodium*~~ preferably, a *P. falciparum* FVO AMA-1 ectodomain.

[0020] As has been described above, preferably at least one putative yeast polyadenylation consensus sequence has been modified in a nucleic acid of the invention. Also,

preferably at least one site in ~~said~~ the *Plasmodium* AMA-1 ectodomain, or functional part, ~~derivative~~ derivative, and/or analogue thereof, that is generally glycosylated by eukaryotic expression ~~systems,~~ systems is removed. Thus, in a preferred ~~aspect~~ aspect, the invention discloses an isolated and/or recombinant nucleic acid sequence according to the invention, wherein at least one putative yeast polyadenylation consensus sequence has been modified. In another preferred ~~aspect~~ aspect, the invention discloses an isolated and/or recombinant nucleic acid sequence according to the invention wherein at least one site in ~~said~~ the ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, that is generally glycosylated by eukaryotic expression ~~systems,~~ systems is removed.

[0021] Figure 1 shows a nucleic acid of the invention, comprising ~~above mentioned~~ the above-mentioned preferred characteristics. Thus, in one ~~aspect~~ aspect, the present invention discloses an isolated and/or recombinant nucleic acid sequence encoding the *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, ~~said~~ the nucleic acid comprising a sequence as depicted in ~~figure~~ Figure 1 (SEQ ID NO:6).

[0022] Considering that in the present invention a nucleic acid sequence was generated that was modified to utilize a ~~yeast's~~ yeast cell's codon usage and that can be used to express high amounts of *Plasmodium* AMA-1 ectodomain in a yeast cell, and the fact that AMA-1 amino acid sequences of various species comprise significant homology, the present invention further provides a nucleic acid sequence encoding *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, capable of ~~hybridising~~ hybridizing to at least a functional part of a nucleic acid of the invention. In a preferred ~~embodiment~~ embodiment, the invention provides a nucleic acid sequence encoding ~~*Plasmodium*~~ *P. falciparum* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, capable of ~~hybridising~~ hybridizing to at least a functional part of a nucleic acid of the invention. Through ~~said hybridisation~~ the hybridization criterion, it is warranted that ~~said~~ the nucleic acid sequence comprises similar expression characteristics (in ~~kind~~ kind, not necessarily in amount) in yeast cells, at least on an mRNA level as the nucleic acid of ~~figure~~ Figure 1 which utilizes a ~~yeast's~~ yeast cell's codon usage. By ~~at~~ "at least a functional part of a nucleic acid of the ~~invention~~ invention" is meant a part of ~~said~~ the nucleic acid, at least 30 base pairs long, preferably at least 200 base pairs long, comprising at least one expression characteristic (in ~~kind~~ kind, not

necessarily in amount) as a nucleic acid of the invention. ~~Preferably but not necessarily said~~ Preferably, but not necessarily, the part comprises an immunogenic property of an AMA-1 ectodomain. In one aspect of the~~ invention said hybridising~~ invention, hybridizing to at least a functional part of a nucleic acid of the invention is under stringent conditions.

[0023] In another aspect, the invention provides an~~ AMA-1 specific~~ AMA-1-specific nucleic acid sequence comprising at least 50 percent homology to a nucleic acid sequence of the invention. An~~ AMA-1 specific~~ "AMA-1-specific nucleic acid~~ sequence~~ sequence" is defined herein as a nucleic acid sequence, comprising at least 20 nucleotides, preferably at least 50 nucleotides,~~ said~~ the sequence comprising a nucleic acid sequence corresponding to at least part of an AMA-1 gene, or comprising a nucleic acid sequence which is complementary to a sequence corresponding to at least part of an AMA-1 gene. In a preferred aspect of the present invention,~~ said AMA-1 specific~~ the AMA-1-specific nucleic acid sequence comprises at least 60 percent homology to a nucleic acid of the invention. More preferably,~~ said AMA-1 specific~~ the AMA-1-specific nucleic acid sequence comprises at least 75 percent homology to a nucleic acid of the invention. In a most preferred aspect of the invention,~~ said AMA-1 specific~~ the AMA-1-specific nucleic acid sequence comprises at least 90 percent homology to a nucleic acid of the invention. ~~Preferably said~~ Preferably, the homology is calculated using the *Plasmodium* AMA-1 ectodomain-specific sequence as depicted in~~ figure~~ Figure 1 as a reference.

[0024] With the teachings of the present invention, a person skilled in the art is capable of generating a nucleic acid sequence comprising an immunogenic property of an AMA-1 ectodomain from another species of *Plasmodium*, for~~ instance *Plasmodium vivax*~~ instance, *P. vivax*, while still using essentially the same nucleic acid sequence as given in~~ figure~~ Figure 1. Such variant nucleic acid~~ will of course~~ will, of course, still be~~ capable to hybridise~~ able to hybridize to at least a functional part of the nucleic acid depicted in~~ figure~~ Figure 1.

[0025] In a preferred~~ embodiment~~ embodiment, the present invention discloses a nucleic acid sequence according to the invention, wherein~~ said~~ the *Plasmodium* belongs to the clade whose members express~~ said~~ the AMA-1 protein as an approximately 83 kDa protein. As has been described before, *P. falciparum* and *P. reichenowi* belong to~~ said~~ this clade. More preferably,~~ said~~ the *Plasmodium* comprises~~ *Plasmodium*~~ *P. falciparum*. More preferably,~~ said Plasmodium~~ *Plasmodium* comprises~~ *Plasmodium*~~ *P. falciparum* FVO.

[0026] A nucleic acid of the invention may, for instance, encode a derivative of a *Plasmodium* AMA-1 ectodomain or part thereof, comprising one or more amino acids from variant AMA-1 ectodomains. The resultant AMA-1 ectodomain or part thereof is a consensus AMA-1 ectodomain having no naturally occurring counterpart. Thus, in one ~~aspect~~ aspect, the invention provides a nucleic acid sequence according to the invention, wherein ~~said~~ the *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, comprises a consensus *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue thereof. In a preferred ~~embodiment said~~ embodiment, part of an AMA-1 ectodomain comprises at least one immunogenic property of ~~said~~ the ectodomain. In another aspect, a nucleic acid of the invention may be modified to utilize codon usage of *Pichia*. Thus, in one ~~aspect~~ aspect, the invention provides a nucleic acid sequence according to the invention, wherein ~~said~~ the yeast is *Pichia*. Preferably, ~~said~~ the yeast is *Pichia pastoris*.

[0027] A nucleic acid of the invention is particularly suitable for efficient expression of the *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof. Therefore, in another ~~aspect~~ aspect, the present invention provides a method for producing the *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, comprising:

-- providing a yeast cell with a nucleic acid according to the invention, and

-- collecting the formed *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue thereof.

[0028] Preferably, ~~said~~ the yeast is *Pichia* yeast, more ~~preferably~~ preferably, *P. pastoris*. Alternatively, it is possible to express a nucleic acid of the invention in another eukaryotic system, for ~~instance~~ instance, baculovirus or a CHO cell. It is even possible to express a nucleic acid of the invention in bacteria. ~~Said eukaryotic systems, and bacteria,~~ Eukaryotic systems and bacteria are more capable of expressing a nucleic acid utilizing ~~yeast's~~ the yeast cell's codon usage, compared to a nucleic acid utilizing *P. falciparum*'s codon usage. However, a nucleic acid of the invention can also be modified to utilize codon usage of ~~said~~ other eukaryotic ~~systems,~~ systems or bacteria. Preferably, ~~said~~ the nucleic acid has been modified to remove at least one putative polyadenylation consensus sequence which is

~~recognised by said~~ recognized by the other eukaryotic system. More preferably, at least one site in ~~said~~ the nucleic acid that is generally glycosylated by ~~said~~ the other eukaryotic expression ~~system,~~ system is removed. Expression of a nucleic acid of the invention in another eukaryotic ~~system,~~ system or bacteria, as mentioned above, is still within the scope of the present invention.

[0029] Of course, by using a method as previously described, *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue will be produced. Thus, another aspect of the invention provides a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, obtainable by a method of the invention. The invention further provides a Pf AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue thereof, produced in a yeast cell. In a preferred ~~embodiment said~~ embodiment, the AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, is purified. As is described in example 4.3, with a method of the ~~invention~~ invention, it is possible to obtain the desired Pf AMA-1 ectodomain, without ~~contaminants like for instance~~ contaminants, such as a 50 kDa contaminant. Thus, in a preferred aspect, the invention provides a method ~~according to the invention,~~ further comprising purifying ~~said~~ the *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue thereof.

[0030] A cell producing ~~said~~ the *Plasmodium* AMA-1 ectodomain, or a functional part, ~~derivative~~ derivative, and/or analogue thereof, by a method as previously described ~~is of course~~ is, of course, also within the scope of the present invention. ~~So yet~~ Yet another aspect of the invention provides an isolated cell comprising a nucleic acid of the invention.

[0031] In yet another ~~aspect~~ aspect, the invention provides an isolated cell comprising a *Plasmodium* AMA-1 ectodomain of the invention or functional part, ~~derivative~~ derivative, and/or analogue thereof.

[0032] *Plasmodium* AMA-1 is particularly well suited for the preparation of a vaccine, because accumulated data have indicated that this family of molecules is a target for protective immune responses. As the present invention provides a way of producing a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, efficiently, the invention also provides ~~a use~~ use of a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the invention for the preparation of a vaccine. A vaccine ~~comprising~~ comprises a *Plasmodium*

AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the ~~invention~~ invention, and a suitable expedient ~~is of course~~ is, of course, also herewith provided. ~~Preferably said~~ Preferably, the vaccine comprises a suitable adjuvant.

[0033] In a preferred embodiment, at least two different variants of *Plasmodium* AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof according to the invention are used for the preparation of a vaccine. Immunization with different variants of a *Plasmodium* ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, provides a broader protection. ~~Said~~ The vaccine preferably comprises *Plasmodium* AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof from different *Plasmodium* parasites from the same clade. More ~~preferably said~~ preferably, the vaccine comprises *Plasmodium* AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof from different *Plasmodium* parasites from the same species. Most preferably, ~~said~~ the species comprises ~~*Plasmodium*~~ *P. falciparum*. A vaccine of the invention preferably comprises *Plasmodium* AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof which display mutual differences, because then a broad protection is even better acquired. An analysis performed by us of ~~*Plasmonium*~~ *P. falciparum* variants has revealed that ~~said~~ these variants display mutual differences of between 1 ~~to~~ and about 30 amino acid residues. Therefore, a vaccine of the invention preferably comprises *Plasmodium* AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof displaying mutual differences of 1-35, more preferably 15-35, most preferably 25-35 amino acid residues. ~~Said~~ The vaccine ~~may for instance~~ may, for instance, comprise ~~*Plasmodium*~~ *P. falciparum* FVO Pf83 and ~~*Plasmodium*~~ *P. falciparum* 3D7 AMA-1 ectodomains or functional parts, derivatives and/or analogues thereof.

[0034] Different variants of a *Plasmodium* ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the invention ~~can for instance~~ can, for instance, be administered together to an individual at the same time. Alternatively, immunization can be performed with one variant, followed by boosting with another variant. This way, protection against common epitopes is boosted and the formation of parasite invasion inhibitory antibodies which are reactive with a whole range of *Plasmodium* strains is enhanced.

[0035] In a preferred embodiment, a vaccine of the invention comprises a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof,

linked to C3d. Preferably, ~~said~~ C3d is covalently linked. C3d is a complement component that ~~crosslinks~~ cross-links receptors on ~~B-cells,~~ B-cells, thus activating them. This results in enhanced antibody production.

[0036] In another preferred ~~embodiment~~ embodiment, the invention provides a vaccine comprising a combination of a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, and another *Plasmodium* immunogenic protein or functional part, ~~derivative~~ derivative, and/or analogue thereof, ~~like~~ for ~~instance~~ instance, *Plasmodium* ~~MSP1.~~ MSP-1. This way, an even broader protection can be acquired. ~~Said~~ The proteins can be present in ~~said~~ the vaccine as separate proteins. Alternatively, ~~said~~ the proteins can be linked ~~together,~~ together or be part of a fusion protein. ~~MSP1,~~ MSP-1, like AMA-1, is involved in the invasion of red blood cells by merozoites. MSP-1 is expressed on the surface of merozoites. Antibodies directed towards the C-terminal end of MSP-1 and reactive with conformational epitopes are capable of blocking invasion *in vitro*.

[0037] In yet another ~~aspect~~ aspect, the invention provides ~~a use~~ use of a proteinaceous molecule capable of binding a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, for the preparation of a vaccine. ~~Said~~ The proteinaceous ~~molecule for instance~~ molecule, for instance, comprises an antibody raised against Pf AMA-1. After administration of ~~said~~ the proteinaceous molecule to an individual, ~~said~~ the individual is, at least temporarily, protected. ~~Said~~ The antibody is preferably a human or humanized antibody. It may be generated *in vitro* using recombinant antibody technology. Alternatively, it may be isolated from blood or serum obtained from an individual vaccinated by a vaccine of the invention. A vaccine comprising a proteinaceous molecule capable of binding a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, and a suitable expedient ~~is therefore~~ is, therefore, also herewith provided. Preferably, a vaccine of the invention is provided wherein ~~said~~ the *Plasmodium* comprises ~~*Plasmodium*~~ *P. falciparum*. More preferably, ~~said~~ the *Plasmodium* comprises ~~*Plasmodium*~~ *P. falciparum* FVO.

[0038] Of course, a vaccine of the invention is particularly well suited for the prophylaxis of malaria. Thus, the invention provides ~~a use~~ use of a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the invention for the preparation of a vaccine for prevention of malaria.

[0039] In a particular embodiment, the invention provides a use of a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the invention for the preparation of a vaccine for prevention of malaria, wherein ~~said~~ malaria is caused by ~~*Plasmodium*~~ *P. falciparum*. A proteinaceous molecule capable of binding a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, is also well suited for the preparation of a medicament. Preferably, ~~said~~ the proteinaceous molecule is used for the preparation of a medicament against malaria.

[0040] A *Plasmodium* AMA-1 ectodomain according to the invention is also well suited for diagnosis of malaria. A person skilled in the art can think of many ways of determining the presence of *Plasmodium* AMA-1 ectodomain, or antibodies against *Plasmodium* AMA-1 ectodomain, in a patient. One way ~~is for instance~~ is, for instance, collecting a blood sample of a patient. ~~Said~~ The blood sample can be administered to a well which contains *Plasmodium* AMA-1 ectodomain of the invention. If the patient contains antibodies against *Plasmodium* AMA-1 ectodomain, ~~they~~ the antibodies will bind to the *Plasmodium* AMA-1 ectodomain in the well. These antibodies can be made visible by many techniques known in the art, for ~~instance~~ instance, by incubation with ~~fluorescent-labeled~~ fluorescent-labeled rabbit ~~anti human~~ antihuman antibodies. Many other ways are known in the art which are still within the scope of the present invention. Thus, the present invention provides a use of a *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, according to the invention for diagnosis of malaria.

[0041] Another embodiment provides a method for, at least in part, diagnosis of malaria, comprising collecting a sample from an individual and providing *Plasmodium* AMA-1 ectodomain or functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, of the invention with at least part of ~~said~~ the sample. Preferably, ~~said~~ the sample is a blood sample.

[0042] Another embodiment of the present invention provides a method for, at least in part, prophylaxis of malaria, comprising administering a vaccine according to the invention to an individual. Yet another embodiment provides a method for, at least in part, prophylaxis of malaria, comprising administering a proteinaceous molecule capable of binding a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue thereof, to an individual. However, an immune response is often only high directly after administration of a

vaccine to an individual. Likewise, protection acquired by administered proteinaceous molecules capable of binding a *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, is often only high directly after administration of ~~said~~ the proteinaceous molecules to an individual. Therefore, a preferred embodiment of the present invention provides a method for, at least in part, prophylaxis of malaria comprising administering to an individual slow release compositions comprising a vaccine of the invention.

[0043] By ~~slow~~ "slow release ~~composition~~ composition" is meant a composition from which a vaccine of the invention is only slowly migrated into the body. This way, ~~said~~ the body contains a vaccine of the invention for a prolonged period, so the ~~immune response~~ immune response will be high during a prolonged period of time.

BRIEF DESCRIPTION OF THE DRAWING

[0044] Figure 1 is a sequence of an isolated and/or recombinant nucleic acid of the present invention, encoding *Plasmodium* AMA-1 ectodomain (SEQ ID NO:6). Surprisingly, this sequence is very well expressed in *Pichia pastoris*, whereas a nucleic acid sequence encoding wild-type Pf AMA-1 ectodomain is not.

DETAILED DESCRIPTION OF THE INVENTION

[0045] The following examples illustrate the present invention. The examples do not limit the present invention in any way. A person skilled in the art can perform alternative ways which are still ~~in~~ within the scope of the present invention.

EXAMPLES

Example 1: Development of synthetic gene for *P. falciparum* FVO strain Pf AMA-1.

1.1 *Original FVO sequence*

[0046] Cryopreserved parasite stocks from *P. falciparum* FVO were prepared from an infected *Aotus lemurinus griseimembra* monkey at the young ring stage of development and DNA was isolated (Gentra ~~systems~~ Systems Inc., Minneapolis, MN) directly from a parasite stock according to the manufacturer's instructions. Pf AMA-1 was amplified by polymerase chain reaction using *Pfu* polymerase (Promega, Leiden, The Netherlands) and primers PF83A:

5′-GGGGGATCCATGAGAAAATTATACTGCGTATT-3′ (nt 1-23 and additional *Bam*HI restriction site, SEQ ID NO:1) and PF83B: 5′-ACGTGGATCCTTAATAGTATGGTTTTTCCATCAGAACTGG-3′ (complementary to nt 1843-1869 and additional *Bam*HI restriction site, SEQ ID NO:2) containing *Bam*HI restriction sites to facilitate cloning in pBluescript. A pool of four independent clones was used for sequence analysis using an ABI ~~Prism~~PRISM™ 310 automated sequencer (PE Applied Biosystems, Foster City, CA) according to the ~~manufacturers~~ manufacturer's instructions, and primers previously ~~synthesised~~ synthesized for sequencing of Pf AMA-1.[10] This resulted in the unambiguous sequence of *P. falciparum* FVO Pf AMA-1, that differs from the FVO AMA-1 sequence available from Genbank ~~(accesssion~~ (accession number U84348) at three amino acid positions. The most notable difference is that the Genbank FVO AMA-1 sequence is one amino acid shorter than any other available AMA-1 sequence, and our FVO AMA-1 sequence does not have this deletion.

1.2 *Alteration of N-glycosylation sites*

[0047] The sequence of gene Pf AMA-1 from the FVO strain that we have ~~established~~ established, encodes a protein of 622 amino acid residues that ~~has 6~~ has six potential N-glycosylation sites. Our previous experience with expressing Pf AMA-1 in baculovirus/insect cells as well as with expressing Pv AMA-1 in *P. pastoris* has shown that these N-glycosylation sites will be glycosylated in eukaryotic heterologous expression systems. As explained above, this is undesirable since native Pf AMA-1 is not glycosylated. ~~Therefore~~ Therefore, we developed a variant that exploited the lack of conservation of N-glycosylation sites in published *Plasmodium* AMA-1 allele sequences. Asn 162 was changed to Lys that is present in that position in the Thai-Tn strain Pf AMA-1 (accession ~~nr~~ number M58547). Thr 288 was changed to Val (present in *P. vivax* and *P. knowlesi* AMA-1; accession ~~nrs~~ numbers Y16950 and M61097); Ser 373 was changed to Asp (present in *P. knowlesi* AMA-1); Asn 422 and Ser 423 were changed to Asp and Lys, respectively (present in *P. knowlesi*, *P. vivax*, *P. chabaudi* (accession ~~nr~~ number M25248) and *P. fragile* ~~AMA-1(accession nr~~ AMA-1 (accession number M29898)) and Asn 499 was changed to Glu (present in *P. chabaudi* AMA-1).

1.3 *Synthetic gene with P. pastoris codon usage*

[0048] The nucleotide sequence with the six changed codons to delete the potential N-glycosylation sites was used to develop a synthetic gene ~~utilising~~ utilizing the codon usage of *P. pastoris* (NIMR, London). Our previous experience with expressing Pf AMA-1 in *P. pastoris* taught us that the high A+T content of the *P. falciparum* gene makes it extremely difficult to express this in *P. pastoris*. There are several A+T rich regions within the coding sequence that are ~~recognised~~ recognized as transcription termination and/or polyadenylation sites in yeast, resulting in truncated mRNAs and no protein production. The sequence of the synthetic gene was designed according to *P. pastoris* codon usage with the aid of the CODOP program.[18] This program allows codon ~~optimisation~~ optimization with host organism preference. It enabled design of an optimal sequence, with strategic insertion of restriction sites, and the generation of oligos of 40 nucleotides in length from both strands of the gene. The resulting set of 92 oligos was rigorously screened for the presence of potential transcription termination signals and undesirable repeats, inverted repeats, and regions of complementarity which could potentially lead to nonspecific intermolecular ~~hybridisation.~~ hybridization. The 20 nucleotide overlap between each 40-mer primer was adjusted to give a melting temperature in the range ~~68-62° C,~~ of 62-68°C, in order to allow subsequent use of the primers for DNA sequencing. Gene synthesis was by assembly polymerase chain reaction (PCR), using the proof-reading *Pfu* DNA polymerase, as described in reference.[18] Blunt-ended PCR products corresponding to each ~~'half'~~ "half" of the gene were cloned into *pMos*Blue (Amersham Pharmacia) and fully sequenced on both strands before subcloning to produce the complete synthetic gene. The final product was again sequenced on both strands. The sequence of the synthetic gene FVO Pf83syn is provided in ~~figure~~ Figure 1.

Example 2: Expression of FVO Pf83syn ectodomain in *P. pastoris*

2.1 Development of expression constructs

[0049] For secreted expression in *P. pastoris* strain ~~KM71H~~ KM71H, we used vector pPICZαA (Invitrogen). This vector provides an N-terminal signal sequence and a C-terminal myc epitope followed by a 6 x His tag for easy purification. Gene fragments have to be cloned in frame with these sequences. Primers for PCR amplification of the Pf AMA-1 ectodomain

were Pf83A: 5'-GGAATTCCAGAACTACTGGGAGCATCC-3' (nt 73-92 and additional *Eco*RI restriction site, SEQ ID NO:3) and Pf83H: 5'-GCTCTAGAATGTTATCGTAACGTAGGCTT-3' (complementary to nt 1615-1634 and additional *Xba*I restriction site, SEQ ID NO:4) or Pf83A and Pf83I: 5'-GCTCTAGACTACATGTTATCGTACGTAGGCTT-3' (complementary to nt 1615-1635, plus ~~stopcodon~~ stop codon plus additional *Xba*I restriction site; this provides the full ectodomain without myc epitope and His tag, SEQ ID NO:5). A 50 µL PCR reaction contained 10 ng template DNA (FVO Pf83syn), 100 ng of each of the primers Pf83A and Pf83H, or Pf83A and Pf83I, 0.2 mM dNTP, 5 µL 10x *Pfu* reaction buffer and 1 unit *Pfu* polymerase (Promega). Amplification proceeded as follows: 1 minute, 94°C, 1 minute 52°C, 1.5 minutes 72°C for 3 cycles; 1 minute, 94°C, 1 minute 60°C, 1.5 minutes 72°C for 30 cycles; 5 minute, 72°C and then stored at 4°C. The resulting 1578 bp PCR product was digested with *Eco*RI and *Xba*I sequentially, and ligated into *Eco*RI/*Xba*I digested pPICZαA in a 1:10 molar ratio. *E. coli* DH5α subcloning efficiency cells were transformed with 5 µL of the ligation mixture and plated on low salt LB plates containing 25 µg/ml zeocin and cultured overnight at 37°C. Colonies were grown in low salt LB containing 25 µg/ml zeocin, plasmids were isolated by standard miniprep methods and ~~analysed~~ analyzed by restriction enzyme digestion. One clone containing the correct insertion for each of the PCR products (named Pf4mH for primers A and H, and Pf11-0 for primers A and I) was used to isolate plasmid DNA for transformation of *P. pastoris*.

2.2 *Pichia transformation and analysis*

[0050] The expression construct was ~~linearised~~ linearized with *Sst*I and 10 µg DNA was used to transform 80 µL *P. pastoris* KM71H cells by electroporation following the Invitrogen protocols. 1 ml of 1M sorbitol was added and the cells were allowed to recover for ~~2h~~ two hours at 30°C. Cells were then plated (25, 50, 100, 200 µL aliquots) on YPDS (1% yeast extract, 2% peptone, 2% dextrose, 1 M sorbitol) agar plates containing 100 µg/ml zeocin, and incubated for 4 days at 30°C. Colonies were picked and grown for 2 days at 30°C in 10 ml of BMGY (1% yeast extract, 2% peptone, 1.34% Yeast Nitrogen Base, 1% glycerol, 0.4 mg/L biotin, 0.1M K-phosphate pH 6.0) in 50 ml Falcon tubes with vigorous shaking. Cells were harvested by low-speed centrifugation, resuspended in 4 ml of BMMY (BMGY with glycerol

substituted for 0.5% methanol), and cultured for an additional 2 days. Cells were harvested and the culture supernatants were ~~analysed~~ analyzed for the presence of Pf AMA-1 ectodomain by SDS-PAGE. Gels were stained with Coomassie Brilliant Blue. All clones ~~analysed~~ analyzed expressed an equal amount of two proteins in the culture supernatant. A 50 kDa molecule of thus far unknown ~~origin~~ origin, as well as an approximately 75 kDa protein, which proved to be the Pf AMA-1 ectodomain, with or without myc epitope and His tag (Pf4mH and Pf11-0, respectively). Expression levels in these small scale cultures are estimated to be 50 mg/L. Our experience with the expression of Pv AMA-1 in *P. pastoris* suggests that this might result in levels approaching 1 g/L in ~~optimised~~ optimized fermentations. No obvious degradation products were visible in the culture supernatants.

[0051] Culture supernatants of Pf4mH were spot blotted on nitrocellulose membranes and incubated with rat monoclonal antibody 58F8 ~~(recognising~~ (recognizing a linear epitope in the N-terminal region of Pf AMA-1), or 4G2 ~~(recognising~~ recognizing a conformational epitope in the ectodomain and capable of blocking parasite multiplication *in vitro*) for ~~1 h~~ one hour at room temperature. After incubation with goat-anti-rat IgG, ~~colour~~ color was developed using NBT/BCIP. Only culture supernatants from the recombinant *P. pastoris* expressing the 75 kDa protein reacted with both mAbs. Control culture supernatants, where the 50 kDa protein, but not the 75 kDa protein, was present did not react with either of the mAbs. This indicates that the 75 kDa protein is the Pf AMA-1 ectodomain and that the secreted material is properly folded. As expected, reactivity with 4G2 was lost when the culture supernatant was reduced with β-mercaptoethanol prior to spot blotting, demonstrating the correct disulfide bond formation within the ectodomain to recreate the 4G2 epitope.

[0052] Purified Pf4mH (sec 4) was used in a standard ELISA to test reactivity with mAb 4G2 and a human serum from an African endemic region. These human sera show high reactivity with conformational epitopes of AMA-1, and hardly react with reduced AMA-1. In this ELISA, strong reactivity with 4G2 and the human serum was detected, whereas a control mAb and a pool of European human serum did not react. As a positive control, similar amounts of ~~baculovirus produced~~ baculovirus-produced Pf AMA-1 were coated on an ELISA plate and incubated with the same serum samples. Similar results were obtained, although reactivity was much lower, suggesting a much better quality for the *Pichia* Pf4mH product.

[0053] In addition, rabbit sera raised against the ~~baculovirus produced~~ baculovirus-produced Pf AMA-1 displayed much lower titers on Pf4mH than rabbit sera raised against Pf4mH. This was not due to impurities in the Pf4mH preparation, since: 1) a very low reactivity of the anti-Pf4mH sera against *Pichia* proteins was observed, and 2) anti-*Pichia* antisera were only marginally reactive with contaminations in purified Pf4mH by ~~Westernblotting.~~ Western blotting. These results indicate that the ~~baculovirus produced~~ baculovirus-produced Pf AMA-1 is less immunogenic, most likely due to the relative impurity of the purified product and/or heterogeneity in folding of the product.

[0054] The homogeneity of the ~~*Pichia* produced~~ *Pichia*-produced Pf4mH was further evaluated by immuno-affinity chromatography, using ~~immobilised~~ immobilized mAb 4G2, reactive with a conformational epitope. It was found that Pf4mH quantitatively bound to the ~~immobilised~~ immobilized mAb, demonstrating that every molecule has the proper conformation.

[0055] To determine ~~an~~ a Pf AMA-1 epitope for mAb 4G2, we expressed separate domains of Pf AMA-1 and combinations thereof using the same *P. pastoris* system as for Pf4mH. These are:

Pf3mH: amino acid residues 25-442 (prosequence, domains I and II);

Pf8mH: amino acid residues 303-442 (domain II);

Pf9mH: amino acid residues 303-544 (domains II and III);

Pf10mH: residues 419-544 (domain III); and

Pf14-0: residues 97-545 (domains I, II, III).

Residue 97 is the natural N-terminus of the 66 kDa proteolytic product of the 83 kDa Pf AMA-1.[21] We established that the parasite-inhibitory mAb 4G2 is only reactive with Pf3mH, Pf4mH and Pf14-0, and not with any of the other proteins. This maps an epitope for 4G2 to domain I or domains I + II.

[0056] Immunogenicity has been evaluated in rabbits ~~by 4~~ by four immunizations of 100 microgram protein formulated in Freunds complete (1st injection) or Freunds incomplete (remaining injections) adjuvant. Injections were given at days 0, 14, 28 and 56, and antisera obtained ~~4 weeks~~ four weeks after the final boost were tested by ELISA and immunofluorescence (IFA). Results for Pf4mH are summarized in Table 1 and IFA data from the other rabbit sera are summarized in Table 2. It is clear that all AMA-1 domains produced by

us are capable of inducing high levels of antibodies that are reactive with the native parasite protein. Using the same protocol, the immunogenicity of two additional fragments are evaluated. These fragments comprise:

1) amino acid residues 97-442 (domain I + II), and

2) amino acid residues 97-318 (domain I).

[0057] IgG was purified from immunized rabbits using standard ~~procedures~~ procedures, and the capacity to inhibit *P. falciparum* growth *in vitro* was evaluated. Parasites at mature schizont stage were cultured in 96-well plates in the presence of different concentrations of IgG from the immunized rabbits, or of IgG from control rabbits immunized with adjuvant only, or purified mAb 4G2 IgG. Radiolabel was added after ~~re-invasion~~ reinvasion of erythrocytes had occurred ~~(approx. 17 h~~ (approximately 17 hours later) and *in vitro* culture was continued for another ~~10 h.~~ ten hours. Parasites were harvested onto glass fiber filters using a Titertek cell harvester (ICN). Incorporation of [^{3}H]hypoxanthine was determined by liquid scintillation spectrometry. Parasite growth inhibition, reported as a percentage, was determined as follows: 100 - ((average $CPM_{experimental}$/average $CPM_{control}$) x 100). The incorporation ~~for~~ of erythrocytes alone was subtracted from all averages prior to determining the percentage inhibition. Control IgG was isolated from rabbits that had been immunized with adjuvant only.

[0058] In this assay, mAb 4G2 at 1 mg/ml gives 50-60% inhibition of invasion, irrespective of the *P. falciparum* strain used. Data for the ~~Pf4mH-immunised~~ Pf4mH-immunized rabbit IgGs are given in Table 1. We used FCR3 as the homologous strain, since AMA-1 differs by only 1 amino acid residue, located in the pro-sequence, from FVO AMA-1. NF54 was used as the heterologous strain and differs by 29 amino acids from FVO AMA-1. Total IgG from rabbits immunized with Pf4mH inhibit invasion of the homologous strain up to 85% at 1.5 mg/ml (a concentration far below standard serum IgG concentrations), and of the heterologous strain up to 58%. This indicates the presence of ~~common~~ common, as well as ~~strain-specific~~ strain-specific, epitopes and demonstrates the capacity of the ~~*Pichia* produced~~ *Pichia*-produced Pf AMA-1 ectodomain to induce potent parasite-inhibitory antibodies.

[0059] Table 1. Analysis of anti-Pf4mH responses

Rabbit	ELISA titer		IFA titer		Inhibition of invasion[1]	
	Pf4mH	pPICZα	FCR3	NF54	FCR3	NF54
1	2.5×10^6	4×10^4	2.5×10^5	1.3×10^5	85%	55%
2	2.5×10^6	4×10^4	2.5×10^5	0.6×10^5	75%	58%
3	1.3×10^6	$<1 \times 10^4$	1.3×10^5	0.3×10^5	50%	44%

[1] evaluated using purified IgG at 1.5 ~~mg.ml^{-1}~~ mg/ml

[0060] Table 2 Immunogenicity of AMA-1 domains

Rabbit ID	Antigen	AMA-1 residues	IFA titer
			FCR3
715	Pf11-0	25-545	2.5×10^5
716			5.1×10^5
717			2.5×10^5
709	Pf3mH	25-442	2.5×10^5
710			2.5×10^5
771	Pf8mH	303-442	1.3×10^5
772			2.5×10^5
773	Pf9mH	303-544	1.3×10^5
774			1.3×10^5
775	Pf10mH	419-544	0.3×10^5
776			1.3×10^5

Example 3: Bulk production

[0061] Pf11-0.1 has undergone a feasibility study for GMP production at a GMP production facility. Pilot fermentations at 5-10 L scale have been performed to assess

parameters that influence proteolytic degradation and yield. The conclusion was that addition of 0.4 mM EDTA to the standard fermentation medium at ~~pH6.0,~~ pH 6.0, as well as methanol induction with a high cell density for a short period of ~~30 h,~~ 30 hours, and immediate freezing of the harvested culture supernatant until ~~processing~~ processing, are all beneficial to prevent proteolytic degradation. For ~~purification~~ purification, best results were obtained by direct binding of Pf AMA-1 on an immobilized metal affinity column activated with $CuSO_4$ (IMAC). This step also removes proteases from Pf AMA-1 resulting in an increase in stability of the partially purified product. The general conclusion of the feasibility study is that it is feasible to produce 1 gram of protein with a minimum purity of 98% for Phase I clinical testing.

[0062] For mid-scale production of Pf AMA-1 ~~ectodomain~~ ectodomain, recombinant *P. pastoris* was cultured in 1L baffled flasks (400 ml BMGY per flask) for 48 ~~h at~~ hours at 29-30°C under vigorous shaking. Cells were harvested and resuspended in 100 ml BMMY, and then cultured for 48 ~~h at~~ hours at 29-30°C under vigorous shaking. Methanol was added to a final concentration of 0.5% every ~~24 h.~~ 24 hours. After low-speed centrifugation, the culture supernatant was harvested. Protein was precipitated with ~~amonium~~ ammonium sulphate (70% final concentration) at 0°C, and the precipitate was stored at 4°C until use.

Example 4: Purification strategies

4.1 *Purification of Pf4mH on Ni resins*

[0063] Additional proof that the secreted 75 kDa protein is the Pf AMA-1 ectodomain comes from purification using Ni resins, since recombinant proteins produced using the pPICZα vector contain His tags that have a high affinity for Ni. The ammonium sulphate precipitate of 50 ml culture supernatant was ~~solubilised~~ solubilized in 2 ml binding buffer (20 mM Na Phosphate pH 7.8, 0.5 M NaCl) and loaded on an 8 ml Ni-agarose column (Probond, Bio-Rad) at 0.2 ml/minute. The column was washed at 1 ml/minute with 15 ml binding buffer, 25 ml of the same buffer pH 6.0, 15 ml of the buffer pH 5.5 and then eluted with the same buffer at pH 4.0. Elution was monitored at 280 nm. The pH 4.0 peak fractions contained a single protein of 75 kDa as determined by SDS-PAGE analysis. Alternatively, the 75 kDa ectodomain could be eluted with a linear 0-500 mM Imidazole gradient in 20 mM Na Phosphate pH 6.0, 0.5 M NaCl. Spot blotting of the peak fractions revealed strong 4G2 and 58F8 binding, indicating that the 75

kDa protein is the His-tagged Pf AMA-1 ectodomain. The 50 kDa protein present in the culture supernatant as well as yellow-stained flavin components were present in the flow through and pH 6.0 wash fractions.

4.2 *Other purification strategies for Pf11-0*

[0064] Other purification strategies are needed when the ectodomain is expressed without His tag, which might be more appropriate for clinical purposes. One way of purifying the 75 kDa ectodomain Pf11-0 away from the 50 kDa protein is the use of hydroxy apatite (HAP)[19, 20] chromatography.

[0065] The ammonium sulphate precipitate of a 100 ml culture supernatant was ~~solubilised~~ solubilized in 5 ml 10 mM $NaPO_4$, pH 6.8 and loaded onto a prepacked 5 ml HAP column (CHT-II, Bio-Rad) at 0.5 ml/minute. Elution with a 20 ml gradient to 400 mM $NaPO_4$, pH 6.8 at 1 ml/minute was monitored at 280 nm. Two overlapping peaks were evident, the first one containing mainly the 50 kDa protein, the second one mainly the Pf AMA-1 ectodomain. Further purification could be obtained by subsequent anion exchange chromatography of the pooled second peak fractions after diluting 1:10 in miliQ water on a prepacked 5 ml UNO Q column (Bio-Rad), eluted with a linear gradient of 0-0.5 M NaCl in 20 mM ~~Tris.HCl~~ Tris HCl pH 7.6. This results in several peaks containing the remainder of the 50 kDa contaminant as well as several degradation products of the AMA-1 ectodomain, and a single peak that contains pure intact AMA-1 ectodomain, as ~~analysed~~ analyzed by reduced SDS-PAGE and Coomassie staining.

4.3 *Production of Pf11-0 without the contaminating 50 kDa protein*

[0066] The 50 kDa protein present in the culture supernatant of our recombinant *P. pastoris* KM71H clones is not common (information from Invitrogen). Transformation of just the empty pPICZα vector into the same batch of *P. pastoris* KM71H also yielded a 50 kDa protein in the culture supernatant upon methanol induction. Untransformed ~~*P. pastoris*~~ *P pastoris* KM71H does not produce this protein. We have now succeeded in preparing a new clone (Pf11-0.1) that only secretes the 75 kDa Pf AMA-1 ectodomain upon methanol induction, and that does not produce the 50 kDa contaminant. This was achieved by picking a single

colony of *P. pastoris* KM71H from a freshly prepared agar plate, made from the original stock of that strain. This colony was used to start fresh ~~cultures,~~ cultures that were transformed with the Pf11-0 vector, resulting in the ~~above described~~ above-described expression.

[0067] Purification as described under 4.2 will provide higher yields of pure Pf AMA-1 ectodomain, since there is no need to separate the 75 kDa product from a major contaminant any more, thus allowing ~~to take~~ recovery of the complete peak fraction 20 from the HAP column for further anion exchange chromatography purification.

~~Brief description of the drawings~~

[0068] ~~Figure 1: sequence of an isolated and/or recombinant nucleic acid of the invention, encoding *Plasmodium* AMA-1 ectodomain. Surprisingly, this sequence is very well expressed in *Pichia pastoris*, whereas a nucleic acid sequence encoding wild type Pf AMA-1 ectodomain is not.~~

References

1. Collins, W.E., et al., Protective immunity induced in squirrel monkeys with recombinant apical membrane antigen-1 of *Plasmodium fragile*. *Am. J. Trop. Med. Hyg.*, 1994. 51(6): p. 711-9.
2. Deans, J.A. and W.C. Jean, Structural studies on a putative protective *Plasmodium knowlesi* merozoite antigen. *Mol. Biochem. Parasitol.*, 1987. 26(1-2): p. 155-66.
3. Anders, R.F., et al., Immunisation with recombinant AMA-1 protects mice against infection with *Plasmodium chabaudi*. *Vaccine*, 1998. 16(2-3): p. 240-7.
4. Crewther, P.E., et al., Protective immune responses to apical membrane antigen 1 of *Plasmodium chabaudi* involve recognition of strain-specific epitopes. *Infect. Immun.*, 1996. 64(8): p. 3310-7.
5. Peterson, M.G., et al., Integral membrane protein located in the apical complex of *Plasmodium falciparum*. *Mol. Cell. Biol.*, 1989. 9(7): p. 3151-4.
6. Kocken, C.H., et al., Molecular characterisation of *Plasmodium reichenowi* apical membrane antigen-1 (AMA-1), comparison with *P. falciparum* AMA-1, and antibody-mediated inhibition of red cell invasion [In Process Citation]. *Mol. Biochem. Parasitol.*, 2000. 109(2): p. 147-56.
7. Hodder, A.N., et al., The disulfide bond structure of *Plasmodium* apical membrane antigen-1. *J. Biol. Chem.*, 1996. 271(46): p. 29446-52.
8. Marshall, V.M., et al., Diversity of the vaccine candidate AMA-1 of *Plasmodium falciparum*. *Mol. Biochem. Parasitol.*, 1996. 77(1): p. 109-13.
9. Oliveira, D.A., et al., Genetic conservation of the *Plasmodium falciparum* apical membrane antigen-1 (AMA-1). *Mol. Biochem. Parasitol.*, 1996. 76(1-2): p. 333-6.
10. Thomas, A.W., A.P. Waters, and D. Carr, Analysis of variation in PF83, an erythrocytic merozoite vaccine candidate antigen of *Plasmodium falciparum*. *Mol. Biochem. Parasitol.*, 1990. 42(2): p. 285-7.
11. Deans, J.A., et al., Vaccination trials in rhesus monkeys with a minor, invariant, *Plasmodium knowlesi* 66 kD merozoite antigen. *Parasite Immunol.*, 1988. 10(5): p. 535-52.

12. Deans, J.A., et al., Rat monoclonal antibodies which inhibit the ~~in vitro~~ *in vitro* multiplication of *Plasmodium knowlesi*. *Clin. Exp. Immunol.*, 1982. 49(2): p. 297-309.

13. Thomas, A.W., et al., The Fab fragments of monoclonal IgG to a merozoite surface antigen inhibit *Plasmodium knowlesi* invasion of erythrocytes. *Mol. Biochem. Parasitol.*, 1984. 13(2): p. 187-99.

14. Kocken, C.H., et al., Precise timing of expression of a *Plasmodium falciparum*-derived transgene in *Plasmodium berghei* is a critical determinant of subsequent subcellular localization. *J. Biol. Chem.*, 1998. 273(24): p. 15119-24.

15. Narum, D.L., G.W. Welling, and A.W. Thomas, Ion-exchange-immunoaffinity purification of a recombinant baculovirus *Plasmodium falciparum* apical membrane antigen, PF83/AMA-1. *J. Chromatogr. A.*, 1993. 657(2): p. 357-63.

16. Kocken, C.H., et al., High-level expression of *Plasmodium vivax* apical membrane antigen 1 (AMA-1) in *Pichia pastoris*: strong immunogenicity in Macaca mullatta immunized with *P. vivax* AMA-1 and adjuvant SBAS2. *Infect. Immun.*, 1999. 67(1): p. 43-9.

17. Garrity, R.R., et al., Refocusing neutralizing antibody response by targeted dampening of an immunodominant epitope. *J. Immunol.*, 1997. 159(1): p. 279-89.

18. Withers-Martinez, C., E.P. Carpenter, F. Hackett, B. Ely, M. Sajid, M. Grainger and M.J. Blackman. PCR-based gene synthesis as an efficient approach for expression of the A + T-rich malaria genome. *Prot. Engineering* 12, 1999. 1113-1120.

19. Urist, M.R., et al., Purification of bovine bone morphogenetic protein by hydroxyapatite chromatography. *Proc. Natl. Acad. Sci. U. S. A.*, 1984. 81(2): p. 371-5.

20. Roelcke, D. and H. Jungfer, Subfractionation of gammaG-myeloma globulins by hydroxyl-apatite column chromatography. *Ger. Med. Mon.*, 1971. 1(1): p. 7-8.

21. Howell, S.A., C. Withers-Martinez, C.H. Kocken, A.W. Thomas, and M.J. Blackman (2001). Proteolytic processing and primary structure of *Plasmodium falciparum* apical membrane antigen-1 (Pf AMA-1). *J. Biol. Chem.* 276: p. 31311-20.

ABSTRACT OF THE DISCLOSURE

A method of efficiently expressing ~~Plasmodium~~ *Plasmodium* AMA-1 ectodomain or a functional part, ~~derivative~~ derivative, and/or analogue ~~thereof~~ thereof, in a eukaryotic expression system. Preferably, the ~~Plasmodium~~ *Plasmodium* AMA-1 ectodomain is Pf AMA-1 ectodomain. This protein may be expressed in yeast, such as ~~Pichia pastoris.~~ *Pichia pastoris.* Efficient expression is possible using a method for producing mRNA encoding ~~said Plasmodium~~ the *Plasmodium* AMA-1 ectodomain in a yeast cell, comprising providing the yeast cell with a nucleic acid encoding ~~Plasmodium~~ *Plasmodium* AMA-1 ectodomain, the nucleic acid being modified to utilize the ~~yeast's~~ yeast cell's codon usage. Preferably, at least one putative yeast polyadenylation consensus sequence in the nucleic acid has been modified. More preferably, also at least one site in the protein that is generally glycosylated by eukaryotic expression systems, has been removed.